The semantics of action : its processing as a function of the task

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Rapports de Recherche

N° 542

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Juillet 1986

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December 1985

Sommaire

Résumé

Le thème central de l'exposé est la façon dont les connaissances sur l'action sont représentées en mémoire et la façon dont elles sont traitées dans une variété de tâches: compréhension de récits, exécution de consignes, description de procédures, adaptation d'une procédure à un nouveau contexte. On considère que ces connaissances sont stockées en mémoire sous forme de schémas d'action qui contiennent des informations sur le résultat de l'action, les différentes façons d'obtenir ce résultat et les prérequis impliqués dans chaque cas.

L'idée de base est que ce sont les mêmes schémas d'action qui interviennent dans les différentes tâches mais que le traitement diffère selon la tâche. Ainsi pour comprendre un récit en vue de le raconter il suffit de traiter le résultat de l'action. En revanche comprendre une consigne pour l'exécuter requiert que soit fait un calcul des actions d'effectuer qui tienne compte de l'état momentané du contexte. Cela implique qu'à la partie du schéma qui décrit le mode de réalisation soit appliqué un processus de planification.

On discute dans cette perspective la description de procédures familières et l'ajustement d'une procédure à un nouveau contexte.

Mots clés: sémantique, représentation des connaissances, schéma, compréhension, procédure, transfert analogique, planification, exécution de consigne.

Summary

The paper presents a theory of how knowledge about action is represented in memory and of how it is processed in different kinds of tasks: understanding a narrative, completing a task using an instruction form, describing a well-known procedure and learning a new one.

Knowledge about action is supposed to consist of action schemas containing information about the result of the action, the different ways this result may be obtained and the prerequisites implied by each of them.

The idea that the same action schemas are involved in the different tasks mentioned above but are not processed in the same way. For instance understanding a narrative in order to retell it requires only the processing of the result of action; by contrast , understanding a recipe in order to execute it implies that the elaboration of the right sequence of actions takes into account the actual context of the action. This implies that the part of the schema which describes the procedure is interpreted by a general planning process.

The way a procedure is described and adapted to a new context is described within this framework.

Key words: Semantics, representation of knowledge, schema understanding, procedure, analogical transfer, planification, execution of instructions.

Knowledge of action concerns three main activities:

- understanding narratives which describe sequences of events and actions;
- understanding what to do to complete a task using an instruction-book, a recipe, etc., planning what to do in order to decide on a sequence of actions necessary to complete the task;
- learning new procedures in an interactive environment.

The questions we want to discuss are what knowledge of action consists of, how it is represented in memory, and how this knowledge is manipulated during the realization of the different activities in which it is involved.

Firstly we will present the basic ideas of a conception of the semantics of action, and then we will show how these ideas may be applied to the analysis of narrative-comprehension, interpretation of instruction-books and learning how to use command systems.

1. Basic ideas for semantics of action

Knowledge of action is made of schemas

The first idea is that our knowledge of actions is made up of schemas which have a common frame.

The notion of schemas has proved very fruitful in the study of the comprehension of stories (e.g. Norman and Rumelhart, 1975; Schank and Abelson, 1977; Kintsch, 1983). It makes it possible to conceive understanding a text as:

a) identifying a schema,
b) filling the slots of the schema with information present in the text,
c) inferring information implicit in the text by assigning default value to variables present in the schema and for which no information is explicitly given in the text.

In quite a different domain and in quite a different way, this notion has been used as a basis of the planning process in studies on artificial intelligence (e.g. Sacerdoti, 1977).

In this perspective an action is considered to be an operation which allows some state of the world to change into another state. Thus an operator is defined by some goal, it has preconditions (the state of affairs necessary for the operator to be applied), and in some cases it may have postconditions. These characteristics constitute the information necessary for a plan to be defined: they are the data basis on which the planning process operates. These, or similar, characteristics have to be introduced into action-schemas since the knowledge about an action is a necessary component of the planning process.

The processing of action schemas depends on the task

The second idea is that the three activities mentioned deal with the same knowledge: action-schemas are used in understanding narratives as well as instructions and learning consists of filling in the elements of an action-schema. What differs from one activity to the other is the way knowledge is used, or more precisely the way the schema is processed in each case: this depends on the specific cognitive objectives connected with the activity.

To validate this idea it is necessary to show that it is possible to give a consistent picture of the main results observed in these different activities by postulating the same knowledge schemas, but by processing these schemas in a different way. This will be done in the second part of the paper.

An action is decomposable into elementary actions

The third idea is that an action may be defined as a set of more elementary actions.

For instance, buying a cake may be described by the following sequence of actions:

a) ask for the cake
b) pay
c) take the cake

These more elementary actions may be described as being made up of still more elementary actions. For example,"pay" may be described as:

- if the amount to pay is large, write out a cheque or use a credit card,
- if not, find a set of notes and coins that add up to the exact amount to pay or, if this is not possible, give a set of banknotes and/or coins that add up to a greater amount and wait for change.

This break down has its end where some primitive actions are defined which may not be broken down into their component parts, not absolutely, but at the level of description under consideration.

An useful level of description to consider is the level of actions which are "cognitively penetrable" (PYLYSHYN, 1984). An action may be said to be cognitively penetrable if it is possible to assign a specific goal to it and if a subject can carry it out by giving himself such a goal. In this perspective a given action is considered to be primitive if a definite goal may be assigned to it but not to its component parts. Thus "take a banknote" or "take the change" will be considered as primitive actions since while each action may be described as a sequence of sensori-motor actions, each of these micro-actions is not initiated separately: the whole action is initiated as a unit.

In fact, the level of primitive action corresponds to the lowest level of detail a subject is able to adopt when he is instructed to describe what he is doing. In short, a primitive action is an action to which a goal may be assigned whereas this is not possible for micro-actions which are component parts of it (see Sebillotte, 1983). Briefly we shall take a primitive action as not being divisible into subgoals.

Declarative and procedural aspects of action

A fourth idea is that the declarative aspect of action (the fact that it leads to a change in the world) may be processed independently of the procedural aspects (the fact that this change was brought about in a certain way).

We clearly distinguish between what the result of the action is (the information which makes it possible to take this action as a goal) and how the action is realized. In other words the declarative aspects as well as the procedural aspects are present in an action-schema. Sacerdoti (1977) as well as Van Lehn and Brown (1980), from an artificial intelligence point of view, have emphasized the importance of considering both aspects of action. We also believe that there are psychological reasons for doing so.

One main reason is that the meanings of some action words express only the result and do not imply anything as regards the way of obtaining the result. For example, when I say that "I put the files into alphabetical order", I mean that the files will be in alphabetical order at the end of the action, but I don't give any indication about the procedure I shall follow to accomplish this i.e. look for the first one, the second one, etc. or each time insert a new file into the already existing series.

It is true that in many cases the "what" and the "how" are indistinguishable because there is only one way to obtain the result. Thus "post a letter" necessarily means "put it into a letter box". Even in this example, however, both aspects of the meaning are present: the goal (the letter in the addressee's hands) and the means to accomplish this (the letter put into the letter box and mailed by the post-office services). According to the circumstances one or the other is intended.

The prerequisites of an action

A fifth idea is that the prerequisites of an action must be represented in a distinct way in the action schema. The prerequisites are the conditions that have to be satisfied in order to carry out the action. If these conditions are not met, something must be done in order to satisfy them: it is the job of the planning process to find out what it is that has to be done.

So the information about prerequisites must be present in an action-schema because it is crucial for planning, but this information needs not stand at the same level. For instance, the preconditions for the action "buying a cake" are:

- to be in a cake-shop,
- to have enough money.

Knowledge about these preconditions has to be in the memory, but we do not think of these preconditions and the way in which they are satisfied each time that we assign a meaning to the sentence, nor do we have to. We must think of these preconditions if we have to plan to buy a cake, but there are a lot of circumstances in which this is only optional. For instance, if we are told that Fred bought a cake, in order to understand, we don't necessarily have to think of the way he went to the cake-shop or of how he got the money.

Consequently, we consider that preconditions are lower in the hierarchy of knowledge associated with the word "to buy" and that this information is only accessed in some circumstances which will be defined later.

Hierarchical action knowledge

As a summary, we consider that our knowledge of action consists of three main parts ordered as follows:

1. The result which is the resultant state of the world (what is done). This allows the action to be taken as a way to attain this result and satisfy this goal.

2. The process or processes that bring about this state of affairs (how it is done).

3. The prerequisites of each process (enabling conditions and associate actions).

We consider that these pieces of knowledge are accessed in this order and that all these pieces are not necessarily accessed. So there are three possible sets of information available:

- result,
- result and process,
- result, process and preconditions.

This presentation somewhat differs from structural network representations (Rumelhart and Norman, 1976) but the difference lies not so much in the content of the representation than in the way elements are accessed in memory. The present view seems consistent with analyses done by Gentner (1975) and Abrahamson (1975): confusions between verbs may be explained by the fact that they have a simular result (for exemple buy and take, sell and give) but different prerequisites (buy and sell imply that a transfer of money has been done before the transfer of objects). There is some evidence that the meaning of verbs of action is acquired according to the order assumed in action-schemas: verbs having the same result but different preconditions are given the same meaning by young children. For instance when required to demonstrate their understanding of possession verbs by reproducing the actions meant by these verbs children at 4 give the same interpretation for buy and sell as for take and give (Gentner 1975). The effect is somewhat more complex when subjects are instructed to state the similarities and differences between pairs of verbs (e.g. take/buy, give/sell): there is no clear cut difference between simple and complex verbs (Bernicot 1981). This shows that it is not the same to evaluate the meaning of a verb in the context of a metalinguistic task and to understand it in the context of action.

The set which is retrieved from the schema will depend on the task to be done. Our basic hypothesis is that the same action-schemas are used in the different tasks listed at the beginning of the paper. What differs according to the task is the type of information retrieved and this depends on general strategies of extracting information from the schema.

In some cases only the goal aspect is considered, in other cases both goal and process are considered, and in still other cases all three aspects are taken into account. In what follows we shall analyze different activities from the point of view of information extraction.

This perspective is quite consistent with the idea that procedural knowledge contains both declarative and procedural aspects (Sacerdoti, 1977, Brown and Van Lehn, 1980). We consider, however, that in some circumstances only some aspects are considered, and in this case the declarative aspects will be the first ones to be considered and will possibly be the only ones.

We shall examine how action-schemas are processed in three types of task:

- execution of instructions,
- comprehension of written narratives,
- expression and elaboration of procedures.

2. Processing of action-schemas in executing instructions

The tasks we consider here are those in which the subject has to complete a complex task by following written instructions which explain how to proceed, each component action being familiar to him. This differs from a problem-solving situation in which the way to proceed has to be worked out. In the case we are considering the subject is told how to proceed and only has to carry out the actions. This covers such situations as filling in a form, cooking from a recipe, making an administrational or bureaucratic request, etc.

It is a well-known fact that it is not easy to follow instructions. The reason is that not everything is said in instructions. Many details of the actions are not stated explicitly and a great deal of what has to be done must be inferred from the subject's general knowledge of actions. Similarly the sequence of actions is not stated at the level of detail necessary to execute it. Understanding and carrying out instructions requires, as we shall see, a planning activity.

We will examine the processes at work in understanding and carrying out instructions.

We will take as a guide line Anderson's idea (1983) that the first step in procedural learning is a declarative stage: declarative knowledge is interpreted using general problem-solving procedures and through this interpretation process declarative knowledge is translated into instructions to act.

As we shall see later, instructions include many declarative components which have to be translated into sequences of actions. We may conceive that the interpretation that allows this translation operates in a similar way to the interpretive process presented by Anderson concerning geometry problems.

Therefore, we shall present first of all the main ideas developped by Anderson et al. (1980) and Anderson (1983). Subjects trying to find proofs for geometry statements (congruence of triangle, angles, sides) are supposed to have stored in memory theorems about, for instance, the different cases of congruence of triangles. These theorems are supposed to be stored in memory under the following form:

description:	e.g. triangle ΔUVW, triangle ΔXYZ
known relations:	e.g. two sides equal in ΔUVW and ΔXYZ the angle between equal in ΔUVM and ΔXYZ
conclusion:	e.g. ΔUVW and ΔXYZ are congruent.

Subjects have general rules to use this type of knowledge.

Examples of these rules are:

- If the goal is to prove a statement and if there is a schema in which this statement is in the conclusion slot, then take as subgoals:
  a. check whether the present situation matches the description given in the schema,
  b. prove the relations present in the schema under the heading: "known relations".

- If the goal is to check whether the description fits the schema consider in turn each element of the description:
  . if the element fits take the next one
  . if not, conclude that the description does not fit

- If every element fits conclude that the description fits.

- If the description does not fit or if proving the relations failed, then look for another schema.

Applying these general rules to the theorem-schemas allows a subject to define what to do if his goal is to prove that two triangles are congruent. The interpretation process transforms declarative knowledge into goals for action. We hypothesize that a similar process is operating in situations where someone has to complete a task, following written instructions. These state the main goals to attain but do not specify the details of actions to be done in order to complete these goals. The detailed sequence of action has to be worked out using general interpretation rules and action-schemas stored in memory which represent common knowledge about action.

We assume that it is such a process that decides which sequence of elementary actions is to be done in order to realize an action described in a set of instructions, when confronted with situations where the elementary actions are familiar but the whole action is not.

This process consists of applying interpretation rules to the terms contained in the instructions using action-schemas that are stored in long term memory.

We suppose that the rules have the following form:

1. Select an action-schema whose goal is the current goal.

2. List the subgoals which are the components of the procedure and transfer this list into the goal pile in working memory (WM).

3. If the subgoal list is not empty, select the first subgoal on the list, go to 4. If the subgoal list is empty, delete the main goal and declare "task done".

4. List the prerequisites of the current subgoal which are not satisfied in the present situation and write this list at the top of the goal pile.

5. If the prerequisite list for a subgoal is empty, execute the subgoal, delete it from the goal pile and go to 3.
If the prerequisite list for a subgoal is not empty, take the first prerequisite on the list, write this goal in front of the subgoal list and go to 1.

The process described is a planning process which may be characterized as follows:

- It proceeds depth first: each subgoal is considered and realized in turn. Before considering the next subgoal, the prerequisites of the current subgoal are considered and satisfied.

- As a consequence, planning is realized directly at the most detailed level. This has to be contrasted with planning in an abstract level which consists of considering high level actions before considering the way each one will be realized (see Sacerdoti, 1977). Such an approach proceeds breadth first.

- As a second consequence, goals are realized independently of each other (linear assumption hypothesis, see Cohen and Feigenbaum, 1983). It may be that trying to realize a goal sets conditions such that prerequisites for a future action are no longer satisfied. Systems like Sacerdoti's (1977) have been devised to prevent such failures: their efficiency lies in their ability to detect interactions between goals.

We consider that this process is basic in the planning of action. As we shall show later people are very poor at solving problems when there are interactions between goals: assuming such a planning mechanism gives us a rather clear explanation of what people do in such situations. We do not mean that subjects are unable to deal efficiently with interactions between goals; indeed, there is clear evidence that, in certain circumstances, they can. What we mean is that considering each goal successively and independently is characteristic of the behaviour of subjects who have no experience in the domain, i.e. of subjects facing a problem solving situation. When subjects gain experience, interactions become noticable to them and, in order to avoid them, they learn to plan at a more abstract level.

We can mention in passing that depth first planning is very economical as regards memory load: one only has to store in working memory the pile of goals related to an action (each subgoal and the goals necessary to satisfy its prerequisites) that have not yet been realized. On the other hand, planning at an abstract level requires that a whole procedural net is saved in memory.

To give a more concrete idea of the way this process operates, we shall take as an example a task which has been studied by Vermersch (1982, 1984).

The task is to make an apple pie following a given recipe. The subjects were young adults on a training course.

The interest of this study in the present context is that it concerns a task, the components of which are very familiar, that has been studied in an extremely detailed way by the author, so that very precise information is available about the detailed course of action.

The task is carried out in the kitchen of a training centre. The recipe is written on a board which is divided into two parts: on the left are the instructions for the actions to be done, and on the right are given the quantities of each ingredient to be used.

We shall consider here only the first phase of the recipe for which the authors present a detailed analysis.

Ingredients

"Pour flour into a mixing bowl" Pastry: 200 g flour (8 heaped tablespoons)

(extract of the recipe)

We shall consider that this is interpreted either as "Pour 200 grams of flour into a mixing bowl" or "Pour 8 spoonfuls of flour into a mixing bowl" and we shall assume that the subjects make the second interpretation. In this case the subject thus understands "Pour 8 times one spoonful of flour into a mixing bowl".

We assume that the meaning of "to pour" is stored in LTM in the form of an action-schema as defined previously

TO POUR INTO (V,X,Y,Z)
SEMANTIC CONSTRAINTS OVER THE ARGUMENTS
V is a human being
X is a non-solid substance
Y is a container containing X before the action
Z is another container containing X after the action
GOAL: HAVE IN Z X at present in Y
PROCEDURE: 1. position the container Y over the container Z
Prerequisites:
1. have Z
2. have X in container Y
2. tip container Y
Prerequisites: none

The action schema is selected by lexical access to the meaning of "to pour" and the variables of the schema are instantiated with the elements of the text. So the data-base in working memory is:

REPEAT 8 times
TO POUR INTO (oneself, flour, spoon, mixing bowl)
GOAL: HAVE IN MIXING BOWL THE FLOUR IN THE SPOON
PROCEDURE: 1. position spoon over the mixing bowl
Prerequisites:
1. have mixing bowl
2. have flour in spoon
2. tip spoon
Prerequisites: none

The main goal "8 times: pour a spoonful of flour into a mixing bowl" and the two subgoals" position spoon over mixing bowl" and "tip the spoon" are stored in the goal pile.

The first subgoal is then considered and its two prerequisites are stored in the goal pile "have mixing bowl" and "have flour in spoon" (see table 1).

The next step is to select an action-schema whose result is "have an object". We shall consider that "get" is such an action-schema. As the only prerequisite in the get action-schema (we shall not detail it here) is that the object to be got is at hand, and as this prerequisite is satisfied (there being a mixing bowl in the kitchen) the action is executed and the goal "have a mixing bowl" is then deleted.

The next prerequisite to consider for the subgoal "position spoon over mixing bowl" is "have flour in spoon". The action-schema to realize this goal is "get flour into the spoon" which has the prerequisites "have flour" and "have spoon". These goals are stored in WM (step 5). They correspond to the action-schemas "get flour" and "get spoon". As these prerequisites are satisfied in the context of the situation, these actions are carried out (steps 6 and 7) and the corresponding subgoals are deleted from WM.

The action "get flour into spoon" is then carried out and deleted from the pile. Then the next subgoal in the pile "tip the spoon", which has no prerequisite, is carried out and deleted from WM. Since every subgoal has been completed, the main goal is deleted and it is noted in WM that it has been completed once.

As this goal has to be completed 8 times, it is reinserted into WM for the second time. Table 1 presents the contents of the goal stack in WM at each step of the processing of the action. The actions "get a mixing bowl", "get flour", "get a spoon", "get flour into spoon" are primitive actions which do not have to be broken down into subgoals and consequently can be carried out immediately.

STATE OF THE GOAL IN WM DURING PROCESSING OF THE ACTION

STEP	GOAL STACK		EVENT HAVING CAUSED THE CHANGE IN THE GOAL STACK
0.	8 times	a	
1.	G	a: have in mixing bowl the flour in spoon	direct transfer
2.	Sb(a) Sb(a)	c: position spoon over mixing bowl b: tip spoon G: a	direct transfer
3.	P(c) Sb P(c)	e: have/get a mixing bowl d: have flour in spoon c b a	prerequisite of c prerequisite of c
4.	P(c) Sb	d: have/get flour in spoon c b a	execution of e <u>get a mixing bowl</u>
5.	P(d) Sb	f: have/get flour e: have a spoon d c b a	prerequisite of d prerequisite of d
6.	P(d) Sb	e: have/get a spoon d c b a	execution of : <u>get flour</u>
7.		d c b a	execution of e: <u>get a spoon</u>
8.		c b a	execution of d: <u>get flour into spoon</u>
9.		b a	execution of c position spoon over mixing bowl
10.		a	execution of b tip the spoon
11.			goal completed
12.	7 times	a	

Table 1: contents of the goal stack at each step of the processing

What differs the second time and subsequent times is that the goals corresponding to the realization of the prerequisite common to the first and second times do not have to be devised. These are: get a mixing bowl, get flour, get spoon. Consequently one jumps from step 2 to step 4 and from step 5 to step 8.

This step by step elaboration and execution of component actions is supposed to take place only on the very first execution of the task. With experience the execution becomes smoother and smoother: this is due to what Anderson (1983) has termed a compilation process, in contrast to an interpretive process. For instance, some steps may be chained when they always follow one another in the same sequence, which is the case in steps 8 to 12 in table 1.

An interpretive process leads to an extreme fragmentation of the task. This is because each microaction does not take place unless there is a corresponding goal in WM: some subgoals are directly transferred from the schema into memory, but others have to be constructed in order to satisfy the prerequisites of the current goal when they are not satisfied in the context of the situation. This fragmentation is rather counterintuitive: it seems that an action as familiar as "pour 8 spoonfuls of flour into a mixing bowl" should be carried out smoothly and without interruption.

In fact the study conducted by Vermersch (1982) shows that such actions are carried out in a way that is far from being continuous. Fifteen macroactions are distinguished in the preparation of the recipe: for example, prepare the flour (which we have considered here) prepare the butter, mix the flour and butter, etc. Each macroaction turns out to be fragmented into several component actions. The criterion used to consider that component actions are not chained together is that the subject has consulted the instructions at least once. As the author remarks "there are very few operations where all the component primitive actions are carried out continuously one after the other: 9 out of 323. Therefore in all other cases the operations are broken down into primitive actions that are carried out with a time gap between each. For example, "put the flour into a mixing bowl" (200 g or 8 heaped tablespoonfuls of flour)", can never consist of chained actions, despite the simple nature of the instruction." (p. 442).

Let us consider as an example the operation of measuring the flour. It may be divided into 4 component actions: get flour, get mixing bowl, measure the quantity of flour, and pour into mixing bowl.

As has been observed by the author, 7 subjects (out of 10) show the maximal fragmentation: there are at least 4 episodes in the completion of the operation. The other 3 subjects show 2 or 3 episodes.

The interesting point to consider is which of the component actions are chained and which are not. In the study mentioned it was observed that actions such as "get flour" and "get mixing bowl" are seldom chained (2 subjects out of 10). On the other hand, actions such as "measure flour (using weighing-scales or a spoon) and pour into the mixing bowl" are usually chained together. In the analysis we have made (see table 1) there is a difference between these 2 types of actions. In the first case a new goal has to be devised and stored in WM before carrying out the second action. In the second case the goal corresponding to the second action is already in WM when the first action is carried out. Then we may expect a shorter delay between these actions, which may lead to them appearing to be chained.

In the study mentioned, 3 subjects (out of 10) present the type of organization of action which consists of processing by object type (get and weigh flour, then get and weigh butter). This type of organization is produced by the elementary planning mechanism we have described. We assume that this is a basic planning process which comes into play in the absence of experience or transfer of experience. Other types of organization which have been observed may be interpreted as being derived from experience on similar tasks. This seems to be usual for subjects grouping actions of the same type: for example, get flour, get butter; measure the quantity of flour, measure the quantity of butter. Such an organization involves planning at a more abstract level: instead of being executed as soon as it may be, an action is delayed until other goals are considered and a similar action is detected.

3. Processing of action-schemas in understanding and memorizing written narratives

In contrast to the task of reading instructions in order to execute them, in the task of reading a text in order to understand it and recall the story it is not necessary, as a rule, to consider the constraints of execution: in other words it is not necessary to consider information contained in the parts of the action-schema dealing with the procedure and its prerequisites. It is usually enough to take into account the result of the action, not the particular way by which this result has been obtained.

The idea is that the goal may be considered independently of the procedure used to attain it and that in many cases (probably most of them) only the goal slot has to be processed.

A first reason to put forward this idea is that a considerable number of words refer only to the result of the action and not to the way it is achieved.

Examples of such terms are "go to", "get to", "arrange in order". These terms are clearly understandable, however only declarative components (not procedural ones) are present in their schemas.

A second reason is that when understanding a narrative, even in cases where the terms have both declarative and procedural components, the emphasis is put on the results of action and, as a rule, the only relevant information is that which deals with modifications in the state of the world, the way these changes have been produced being generally irrelevant.

We assume that when understanding a narrative only the declarative components of meaning are processed unless there are elements which cannot be interpreted without considering the procedural aspects of action. This is the case when reading: "a man decided to go to the neighbouring village. Halfway there, because he felt tired, he stopped off at an inn." . We must consider that the journey is made on foot (or bicycle), because it is the must plausible way to explain why the traveller is tired.

If we do not make this assumption, it seems very difficult to explain the resultant paradoxical fact, which seems to have been overlooked. Reading a narrative seems to be very fast, compared to reading a recipe or reading the text of a problem such as the tea ceremony (Hayes and Simon, 1974). As far as we know these situations have not been compared directly in a standardized form, but it is clear that in none of the many studies on the understanding and recall of narratives, no similar segmentation of the information taken has been reported, nor so frequent rereadings as this usually observed in reading instructions.

However some puzzling results seem to be easily explained by the idea that understanding a text in order to recall it or tell it back does not require the same processing as understanding it in order to carry out what is said in the text. Paris and Landhauer (1976) have shown that sentences such that "he dug a hole using a shovel" are better recalled that sentences which do not mention how it has been done "he dug a hole". The effect is particularly important with young children. However when these same children are instructed to mime what is said in the text, there is no longer any difference whether the instrument is explicitly mentioned or not. In our interpretation these children process only the result of the action when they have to retell the story, while they process the way the action has been done when they have to mime it.

The reason for the difference between narratives and instructions is that it is not the same information which is processed in both cases. In understanding a narrative, the only relevant information is usually that which concerns the goal. In reading instructions, on the other hand, it is necessary to process the information concerning the procedure and its prerequisites in order to construct a series of actions, and not simply a description of changes in the state of the world brought about by events.

In studies concerning the understanding of texts the schematic approach has been very popular (Kintsch, 1974; Rumelhart, 1974; Schank and Abelson, 1977) but has been developped in a rather different perspective to the present one. Schemas are used to describe knowledge about scenarios or to represent the general organization of the narrative (text grammar). They have seldom been used to represent dependency relations between goals and subgoals, as is the case for the action-schemas proposed here, since the relation between goal and procedure may be viewed as a class-subclass relation.

There are, however, two notable exceptions to this general trend: the studies by Graesser and coll. (Graesser, 1978; Graesser et al., 1979; Graesser et al., 1980; Graesser et al.,1981) and those by Brewer and coll. (Lichtenstein and Brewer, 1980; Brewer and Dupree, 1983).

In order to infer the hierarchical organization of actions Graesser analyzes the responses to two types of question: questions of the "why" type and questions of the "how" type. The "why" questions provide information about superordinate actions, the "how" questions about subordinate actions. This technique makes it possible to draw a graph representing the dependency relations between the actions involved in a narrative.

Understanding of the text is measured through a recall task or tests in which the subjects have to evaluate the veracity of an event. The main result is that actions at higher nodes in the graph are better recalled than those at intermediate ones, and that those at intermediate levels are themselves better recalled than actions lower in the goal-subgoal hierarchy. Another result is that actions which are not explicitly mentioned, but which have to be inferred get higher recognition scores when they correspond to higher nodes in the graph.

Consistent results have been reported in studies by Lichtenstein and Brewer (1980). Subjects are shown a scene on video tape and have to recall every event they can remember. The superordinate actions, which are goals for the other actions, are better recalled than subordinate actions: the frequency of correct recall is .96 vs .84 for a first scene and .66 vs .44 for a second one. Moreover the conditional frequency of recalling a superordinate event, given the fact that the subordinate event has been recalled, is markedly higher than the conditional frequency of recalling a subordinate event given the fact the superordinate one has been recalled (.83 vs .69 and .82 vs .65). It is to be noted that the same results are observed whether the scene is narrated or presented visually on a film.

Brewer and Dupree (1983) report complementary results which are quite consistent with those mentioned above. Subjects are shown pairs of actions which are linked to each other by a means-end relation or pairs of actions which are unrelated to each other. The recall frequency is 2 to 3 times higher in the first case. In another experiment subordinate actions viewed previously are recombined with new goals (a same action is used for a new goal) on actions previously presented as goals are recombined with new subordinate actions (the same goal is realized by another means). When the goal is concerned by the change (first case) old actions are well discriminated from new ones in a recognition test. However a great number of confusion errors are observed when the change involves the means rather than the goal. This indicates that the information about the goal of the action may be kept in memory whereas the detail of what has to be done in order to attain the goal is lost.

All these data show that schemas, which allow a categorization of actions, are involved in the comprehension and memorization of a scene or a narrative. The role played by schemas, however, may be interpreted in different ways.

A schema may be used at the time of recall to infer an action which has not been stored in memory. This idea is supported by Graesser et al. (1981) and by Brewer and Dupree (1983). The theory is that a subordinate action need not be stored in memory: since it is executed in order to satisfy the prerequisite necessary for the execution of another action, it may be inferred from the action to which it is subordinate. For instance, to take an example from a story used by Graesser et al. (1981), the fact that a dragoon kidnapped the three daughters of the czar while they were walking in the woods implies that the dragoon had come to the place where the czar's daughters were.

Another interpretation is that a schema is used to encode information and the difference may be due to the fact that the different parts of a schema have not been processed in the same way at encoding. In our view, in situations which involve the understanding of a story with the purpose of recalling it, it is the result of an action which is important and not the procedure that leads to the result. In such a task, information related to the state of the world resulting from action are encoded and memorized.

Information regarding the procedure is not processed unless it is considered necessary in order to understand what follows in the story.

The hypothesis that the subordinate actions are not stored in memory because they may be inferred may explain why superordinate actions are better recalled than subordinate ones. It does not however explain why other types of actions are accurately recalled; namely, the subordinate actions which are connected with a large number of other actions, particularly those which are preconditions for other actions. It is clear that it is through their result that they are connected to their superordinate actions, not by the sequence of events that characterize them. They have to be encoded as regards their result and have to be memorized as such.

Experiments on memorization of actions show two things. First, as regards memorization, the goal-subgoal relation plays the same role as the category - exemple relation: the result is retained and detailed information about the way it has been obtained is lost, in the same way as specific information about objects may be lost while more general information is retained in a delayed test.

Secondly, the way actions are processed in a story seems to be very different from the way they are processed in instructions. These differences may be explained by the hypothesis that in a story only the result of action usually has to be considered whereas in reading instructions a further processing is required: the precise way the result has to be obtained as well as the necessary pre-requisites have to be considered. This means that understanding in order to execute is not the same as understanding in order to recall (or report).

4. Knowledge of action in expression and elaboration of procedures

A particularly important class of situations involving knowledge of action-schemas is that in which a subject knows how to do something and has to explain how he does it, and those situations where he does not know how to do something and has to learn it (problem-solving).

4.1 Description of procedures

What we intend to show in this section is that in a situation where subjects have to describe how to proceed in order to realize a specific task, they may adopt one of two types of description: one in which they enumerate the detailed sequence of actions to do in the order which must be followed, or else by expressing the constraints of the actions (the goals of the action, the procedure and its prerequisites), not their temporal order.

This means, in our opinion, that they use the same basic knowledge but that they process it differently. In the second case knowledge about action is expressed, while in the former it is contained in the memory schema, i.e., the description constraints and relations (result of action, subgoals of the procedure, prerequisites of the subgoal). The first description corresponds to an interpretation of the action schema, which gives a mode of realization of the action. The interpretative mechanism is the same as the planning mechanism described to provide an interpretation of instructions.

To illustrate this point we shall refer to two studies, one by Politzer (1975), the other by Sebillotte (1984). In the first study subjects had to describe how to play a popular game in France, the game of "pétanque" which is a variety of the game of bowls. They were very familiar with this game and had to explain to the experimenter, as they would to someone unfamiliar with the game, how to play the game and what rules to follow. They were told to be careful not to omit anything and to be sufficiently explicit so that the person would be able to play a game by himself.

We shall present at first what we consider to be the schema which we suppose to be in the memory of an expert in the game. We shall concentrate on what a game consists of, which is the object of the description required from the subjects by Politzer. A game is part of a match, a match being a sequence of games ending with the obtention of a given number of points by a team. A game consists of throwing the jack and then the players of each team throwing their bowls and the game ends when one of the teams has been awarded a certain number of points.

Following the general schema of a procedure, we consider that a game has:

. a goal
. a course of actions (process)
. an outcome
. a set of prerequisites

The course of actions is:
. a series of turns (throwing the bowl)
. a stop rule

A turn is described as:
. a goal
. an action
. prerequisites

We distinguish two types of prerequisites:
. prerequisites concerning the situation
. prerequisites concerning actions

The first ones are the material conditions that allow a game to take place (persons, objects, place). The second ones concern actions which must have been done so that a given action may take place.

In our presentation, the material prerequisites are considered as being the first information in the schema. The first reason is that, as compared with the prerequisites concerning actions, these elements are constant for every phase in the game.

The second reason, as we shall see later, is that they do not appear at the same moment in a subject's description.

In the presentation of the game-schema, as it appears in table 2, we adopt an exposition of rules similar to the one Politzer has used to analyse the interviews. The only difference is that in Politzer's analysis the goal of a game is not set apart from the goal of a throw, nor is the stop rule differentiated from the awarding of a certain number of points.

If we refer to the two ways of processing an action-schema presented above, we can easily imagine two ways of giving information about the game of "pétanque".

The first account is declarative: the information is given in the order it appears in the schema, i.e. it emphasizes properties and proceeds from the more general (description of the goal) to the more particular (description of the process and its prerequisites).

The second account is based on an instantiation of a game and describes the actions in the order they are carried out. The course of actions is deduced from the schema by an interpreting process like the one that has been described in the section concerning understanding of instructions. Prerequisites of the game are considered first, then prerequisite of a throw, and then the description of a throw, of the sequence of throws, the stop rule, and the outcome.

Material prerequisites are a special case. As they describe the material context of the game and consequently are information to which every other piece of information refers, we can expect that they will appear at the start of both types of description.

The declarative account will look like this.

There are two teams, each player has several balls, there is a jack, the game is played outside on the ground (1 in table 2).

In a game each team tries to get as many points as possible (2.1).

At each throw a player tries to place his ball (or one of his teamate(s) as close possible to the jack (2.2.1.1).

1. Material prerequisites
    - 1.1 the game is played by two teams (each having one or more members)
    - 1.2 each player has several bowls
    - 1.3 there is a small ball called the jack
    - 1.4 the game is played outside on the ground
2. A game
    - 2.1 goal: gain the greatest possible number of points
    - 2.2 course of action
        - 2.2.1 a series of turns
          a turn is
            - 2.2.1.1 a goal: to have the bowl as close as possible to the jack and nearer to it than the opponents'nearest ball
            - 2.2.1.2 an action
                - 2.2.1.2.1 a player throws a bowl
                - 2.2.1.2.2 there are two types of throws:
                  either to throw the bowl so that it is as close as possible to the jack,
                  or else to throw the bowl in order to knock an opponents' bowl away from the jack
            - 2.2.1.3 a prerequisite: the team whose turn it is to throw is he team to which the nearest ball to the jack does not belong
        - 2.2.2 the stop rule: when there are no more bowls to throw
        - 2.2.3 an outcome: one point is awarded for each ball nearer to the jack than the opponents' nearest bowl (to the jack)
    - 2.3 a prerequisite: a player has thrown the jack
        - 2.3.1 a prerequisite to 2.3: a spot has been chosen from which to throw

Table 2. Schema representing knowledge about the game

A throw may be to place the ball near the jack or to knock out an opponent's ball (2.2.1.2).

Each team plays in turn: the turn is when the ball closest to the jack belongs to the other team (2.2.1.3).

When every ball has been thrown, the points are counted up (2.2.2-2.2.3).

At the start of the game a player throws the jack (2.3).

Before this, a spot from which to throw has been chosen (2.3.1).

On the other hand, the temporal account will look like this.

There are two teams, each player has several balls, there is a jack, the game is played outside on the ground (1).

A place from which to throw the jack is chosen (2.3.1).

A player throws the jack (2.3).

Each team plays in turn: the turn is when the ball closest to the jack belongs to the other team (2.2.1.3).

The player may throw to try and gain points or to knock out his opponent's ball (2.2.1.2).

A player tries to have his ball (or one of his teamate's) as close as possible to the jack (2.2.1.1).

When every ball has been thrown, points are counted up (2.2.2-2.2.3).

We shall now examine in which order the subjects interviewed by Politzer gave information about the game.

As in Politzer's analysis categories 2.1 and 2.2.1.1 are mixed up as well as categories 2.2.2 and 2.2.3, these categories will be pooled in the presentation of the results of Politzer's experiment.

The expected order in a declarative account is:

[1] [2.1,2211] [2212] [2213] [222-223] [23] [231]

and for the time-order sequence account is:

[1] [231] [23] [2213] [2212] [21,2211] [222,223]

A summary of results obtained by Politzer is given on the graph presented in figure 1: the nodes in the graph are the information of table 2, an arrow is drawn between two nodes when the information corresponding to

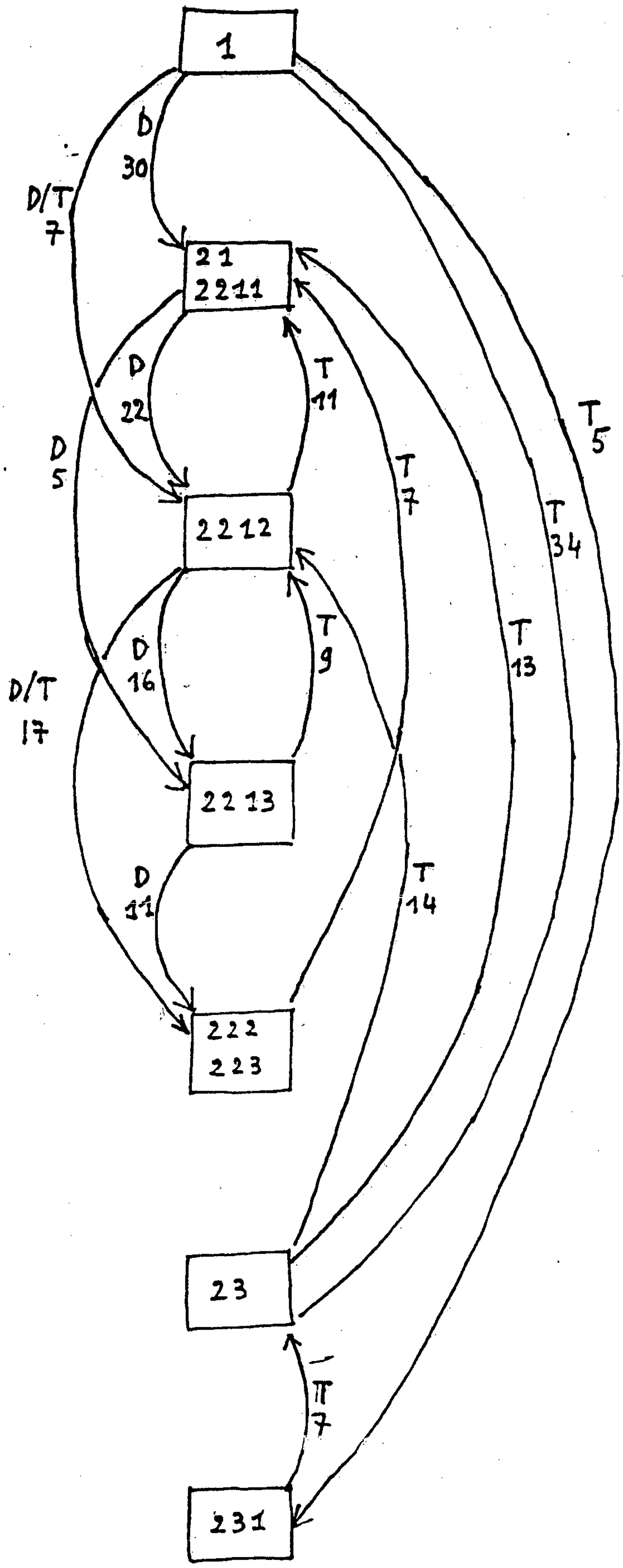

Figure I Transitions between items of information
(adapted from POLITZER 1975)

these nodes has been given in succession by at least 5 subjects (out of 60). For each transition the number of subjects having given both pieces of information in succession is written as well as a letter D,T or D/T. D means that the transition is consistent with the declarative account and inconsistent with the time-order account (note that a piece of information may be missing, causing a leap), T means that the transition is consistent with the time-order account and inconsistent with the declarative account, D/T means that the transition is consistent with both accounts.

It appears (figure 1) that both accounts are represented with an approximately equal frequency. Temporal order is followed by about forty subjects: 5 subjects show the paths 1 - 231 - 23 and 34 subjects go directly from 1 to 23 (231 missing). Then these subjects describe either the action (2212) and then the result (223) (the goal is missing) either the goal (21,2211) and then the result (223).

Another group of about 30 subjects state the goal (2-1,2211) immediately after the description of the physical situation. Only after that do they describe the action (2212), its prerequites (2213) and the result (222-223) or they describe the action and immediately after the result, omitting the prerequites of the action. The subjects of this group usually omit the prerequisites of the game (2,3 and 231).

What is important is that there are only 2 transitions in the graph which are a D/T transition: the transition from action (2212) to result (222-223) and the transition from situation (1) to action (2212) which are consistent with a D as well as with a T account. There is no transition in the graph which is neither consistent with a D account nor with a T account. Remember that the transitions present in the graph are those which have a frequency of at least 5. This means that the two types of exposition we have distinguished may account for every significant transition.

Why some subjects adopt one style of exposition rather than the other may depend on the subject's degree of expertise (it is likely that the exposition emphazising the constraints of the task rather the temporal course of events requires a higher degree of expertise and would be favored from a pedagogical point of view). It may also depend on the way the subject interprets the instructions which explain how to play the game.

Is it legitimate to generalize these results to tasks involved in daily work? A study by Sebillotte (1984) shows that these results may be probably extended to clerical work. She has studied different secretarial tasks: secretarial tasks in a team of research workers, a medical secretary's tasks and secretarial tasks in a lawyers office. The employees were interviewed by an experimenter and had to explain what their work consisted of and how each type of activity was fulfilled.

The subtasks may be described by an action and an object, for instance:

. send: an invoice, an order, a report

. record: an invoice, a contract

. get a signature for/ an order, an invoice, a contract

A first result is that complex tasks such as dealing with orders are described as a series of subtasks which are limited in number and which can be analyzed within a standard format, such as the one we have described previously. These subtasks either are primitive actions or can themselves be broken down into more elementary actions.

A second result is that at the beginning of the interview subjects describe their task in general terms: they mention the major components of the task which may be interpreted as subgoals. It is only when asked by the interviewer to be more explicit that the subject describes the detailed course of the actions to be done and in the order they are done. We may say that the description is based at first directly on the content of the schema and then relies on an interpretation of the schema which yields the temporal course of action.

Consider for instance the following fragment and the analysis made by S. Sebillotte (1983).

It is apparent that the goal is expressed before the preconditions and the procedure. The way the task is described seems to be a close transcription of the supposed content of the action-schema. It is only upon request that the

PROCEDURE GIVEN BY SUBJECT	SUBJECTS MODEL
- I send the travel requests (to attend a conference)	GOAL : Send off a travel request PREREQUISITE : have a completed form which has been checked, signed and filled.
. When a member of the team decides to attend a conference, he tells me, and either he or I fill a form.	. Realization of the first pre-requisite : subgoal 1 : fill in the form Prerequisite : have a form Action : write in the necessary information
Q : What does that involve ? . I take a form from the drawer. Either the person concerned or I fill it out (reason for the trip, date, title of the conference).	
. I check that the form has been correctly filled out, and that all the necessary information is present, if necessary with a pamphlet from the conference, especially if it is the person concerned who has filled out the form.	. Realization of the second pre-requisite : subgoal 2 : check the data Prerequisite : have a completed form and a reference document containing certain data (or their real value known) Action : consult the data
. I have the person concerned sign the form	. Realization of the third pre-requisite : subgoal 3 : get the person concerned to sign the form Prerequisite : have the completed Action : sign the form
. Then the project leader AB signs	. Realization of the fourth pre-requisite : subgoal 4 : validate the request a second time (by the project leader) Prerequisite : have the form comleted by the person concerned Action : sign
. I make a photocopy which I file in chronological order in the file marked "mission"	. Realization of the fifth pre-requisite : subgoal 5 : file the request Prerequisite : have the completed form checked and validate twice Actions : . make a copy . file
. I send the original by the internal mail service to the management, if necessary enclosing any information as I do for orders.	ACTIONS : . take an envelope . write the address . enclose the form (and any other necessary papers) . put it in the out tray

Table 3 (cf. S. SEBILLOTTE 1983)

subject gives a detailed account of how he proceeds. This excerpt is representative of that which is observed at the start of the interview. This is to be contrasted with a description in which prerequisites are given first, then the course of action and goal and which reflects the temporal succession of events. This is usually observed later on in the interview.

As a conclusion two main strategies appear in the expression of procedures: one which emphasizes the goals and constraints of the action and one which follows the temporal course of action. The first one is thought to be a direct transcription of the content of the action-schema (the clarity of this expression depending on the precision and degree of consciousness of the action-schema. An action schema may be precise enough to allow an adequate control of action in the situation but not a sufficiently precise verbal expression in the absence of the situation. The second one is thought to be the result of an interpretation process which is the same as the planning process which yields the sequence of actions to do in the actual situation.

4.2 Elaboration of a new procedure from a known procedure

The situations meant here are those in which a given procedure is known in order to attain a definite goal but is no longer usable because new constraints are introduced such that a new one has to be devised. This state of affairs (problem solving situations) typically arises when a definite task has to be done using an electronic programming or command device. We intend to show that some striking phenomena observed in these situations fit quite well within the conceptual framework we have developed.

A fundamental result is that the goal structure of the known procedure executable by hand is transferred into the new situation, leading to the following representation of the problem: take each subgoal of the known procedure in turn and try to find a way of realizing the subgoal using the actions allowed by the device. This is observed even when there is another procedure which, given the possibilities provided by the device, is simple, but which requires a restructuration of goals. The subject maintains the old goal-structure as long as possible even at the cost of having to develop quite complicated solutions to satisfy each subgoal. It is only when constraints are introduced which make it impossible to cope with the problem using the transferred goal structure that the subject tries to change his representation of the problem and sets up a new goal structure.

This idea has been developed by Hoc (1981) who has presented an experiment illustrating quite well this point (see also Richard, 1983). The task simulates updating stock files: the subject has to store into a new stock file the number of each item knowing the quantity left for each item the day before and the moves (in or out) that have taken place during the day.

There are three phases differing according to the constraints of the device (information visible and commands available). In the first phase the constraints are such that there is a one to one mapping between the component actions of the procedure when realized with paper and pencil and when realized with the command device. This procedure is centered on the processing of each item: each item of the list is considered successively and is categorized according to the number of moves in which it is involved (no, one or more than one): for each case an appropriate sequence of actions is carried out. In a third phase a different representation of the task is required: the iteration has to be done not on items but on moves concerning the items (moves concerning a given an item are supposed to have been regrouped and items are ordered). Each move is processed in turn: if the current move involves the current item (which is indicated by comparing the number of the current item and the number of the current move) updating is ended for the current item and a new item has to be introduced as the current item; if this is not the case updating has to be completed for this item and a new move has to be introduced as the current move. The second phase allows both representations of the task to be used but the procedure is more complex when using the first one.

Not surprisingly, in the first phase subjects transfer the goal structure of the hand-procedure known for the task. The transition to the second phase presents no major difficulty as compared with transition to the third phase, in which many errors are observed. It appears then that in the second phase subjects were adapting the procedure used before and did not attempt to change the goal structure of the task until the third phase.

These results are consistent with the idea that in a problem solving situation the subject looks for the available action-schemas and if there is one which has the same goal as the present situation, the subgoals of the corresponding procedure in the action schema are listed and each is considered in turn: if there is an action schema corresponding to this subgoal which has a procedure executable in the present situation, this procedure is executed, if this is not the case the subject sets himself the problem of finding out a procedure to attain this subgoal with the constraints of the present context. It is not until the subgoal has been realized that the next subgoal is considered. This process is of the same type as the planning process which we have supposed to be the interpreting process which operates an action schemas and defines the appropriate sequence of actions.

The idea of analogical transfer (see Richard 1985) coupled with the idea of a depth-first planning process operating on each subgoal and each precondition successively gives a straightforward explanation of why some problems may be so difficult to solve. There are problems in which two preconditions have to be considered simultaneously so that a single goal has to be found satisfying both, and which at the same time allows analogical transfer of a procedure in which these preconditions are processed as successive subgoals. Due to the planning process the second goal is not considered until the first one has been realized which may have as a result that the problem becomes unsolvable.

A famous example is the Tour de Hanoï problem. In order to move a disk two constraints have to be satisfied simultaneously: there must be nothing on the top of the disk to be moved and there must not be a smaller disk at the place where the disk is to be moved. As a consequence it is necessary to set up as a goal to build a pile with the blocking blocks on the other peg than the "to" and "from" peg.

We have shown (Richard, 1982) that which makes the 3 disks problem unsolvable for many young children (7-8 years old) is that they transfer a procedure which would be feasible if the number of available places for a disk was larger than 3: first spread out the disks which are on the top of the largest one (which is a procedure satisfying the first constraint but not the second) then rebuild the tower in the right place. As when they have attained the first subgoal they cannot realize the second goal, they come back to initial position and try another way of spreading out the two smaller disks. This new way of realizing the first goal no longer makes it possible to realize the second subgoal so that they come back to the earlier position and repeat that until they try another move or abandon the problem.

A similar difficulty of restructuring constraints in a way differing from the sequence of subgoals in a known procedure has been observed with adults having to solve, with the aid of a pocket calculator, an elementary problem of statistics, computing the variance of a distribution (Friemel et al., 1982).

A special case of elaboration of a procedure is where one has to translate information and specifications concerning a given process into instructions for a device to be used to control the process. Before writing the instructions it is recommended, especially for novices, to draw a representation of the process which has the form of a sequential graph (called GRAFCET: in this graph operations are stated in the order in which they are to be realized and are preceded by their enabling conditions).

Morais and Visser (1985) have studied how novices elaborate such graphs. Subjects had to produce a first graph in which operations and preconditions are stated verbally on the basis of what is said in the specifications, then they had to write a second graph in which each operation and condition had to be expressed as instructions for the automaton. It is interesting to analyze how the representation of the process, as it appears in the first graph, is built from information contained in specifications.

The analysis of what is stated in the first graph shows that it is necessary to distinguish two types of information:

- Operations realizing the overt goals of the process (transferring a box from a conveyor belt to a table and from the table to another conveyor belt) and conditions concerning the objects involved in these operations (the box must be there, which is signalled by a detector).

- Operations which are to be done to set up the preconditions required for the preceding ones (pulling back the jacks and starting the temporisation).

Information of the first type appears on the first graph for every subject, and for 6 subjects (out of 19) it is the only information present in the second graph. For 7 subjects the information of the second type appears only on the second graph or at the end of the elaboration of the first graph. For the remaining subjects this information appears right at the beginning.

One can remark that information of the first type concerns overt goals and conditions which are true for every way of realizing the process, particularly when it is done by hand (it is necessary to wait for the box to be there before pushing it). The information of the second type concerns prerequisites which are specific to the mechanical process used: jacks have to be pulled back in order to allow them to be shoved out to push the box.

So we may say that for two thirds of the subjects the information taken into account in the first representation of the process they elaborate is quite dependent from the reference to a representation of the process such as it would be executed by hand. It is significant that although it is quite explicit in the text, the information about specific prerequisites is left out. This difference is easy to interpret within the framework we have proposed to represent knowledge about action. The action-schema corresponding to "to push" has been activated during the reading of the text containing specifications and the representation built is a refinement of this schema, the agent for pushing being jacks instead of being a person. The first representation reduces to an instantiation of this schema with the replacement of hand-pushing by shoving out a jack and the replacement of checking visually the presence of the box by checking by means of a detector.

The final representation adds to it the moves and checking necessary to fulfill the prerequisites specific to the mechanical process. It is obvious that this representation is modelled on an action-schema and on the representation of how the process would be done using this action schema.

Concluding remarks

A main idea of this paper is that knowledge about action takes the form of schemas in which information is stored at three levels:

. result of the action (and possibly general prerequisites)
. processes (one or more) allowing the result to be got
. prerequisites of each process

The information in the schema is supposed to be accessed in that order so there are three ways of processing the information:

. processing goal alone, which is most usual in understanding stories
. goal and process, which is sometimes necessary in understanding stories
. goal, processes and prerequisites of the process, which is necessary when one has to carry out the action.

In this third case a planning process is necessary to interpret the schema and compute the sequence of actions to do in the present context. In the first two cases it is not necessary, unless it is needed to produce inferences about prerequisites of the action in order to make some part of the text understandable: information about goal and actions is retrieved directly from memoy and used as such in the interpretation of the text.

The theory predicts different ways of processing a text as a function of the task in which it is involved. This implies that understanding a text means different things depending on whether the text is to be retold or is to be translated into actions.

This perspective provides some insight about how a subject explains what he knows about activities he is familiar with. According to the theory there are two characteristic ways of explaining knowledge about activity: stating directly the result, the process and the constraints of the action or stating component actions in the order they are done. The first way corresponds to reading information in the memory schema corresponding to this action, the second one is an interpretation of the content of the schema by means of a planning process.

The analysis of two examples has shown that these two modes of description are the most representative ones. Further research is needed to explore how fruitful this idea is. It has the merit of providing hypotheses about which aspects of action are easy to retrieve from memory and which aspects are more difficult. As the different types of information are supposed to be accessed in a fixed order, we may derive hypotheses about the degree of accessibility and consequently the degree of consciousness of these different types of information.

We may expect that the goal and realization process are accessible in a recall situation. Conversely we may expect that specific prerequisites may not be accessible to recall but only to recognition, making it possible to detect whether the present situation matches the preconditions or not in the real context or when the situation is simulated mentally. This position is consistent with the Piaget (1974) theory that consciousness goes from periphery (goal) to center (means and control).

Another interest of the theory is that it provides a basis for analogical transfer, which appears to be a major factor in problem solving situations.

In our view analogical transfer consists of transfering the goal-subgoal structure of a similar well known situation to the present one: what is transferred is a list of subgoals so that the problem is now to work out another way of realizing each subgoal that satisfies the new constraints. This explains why new procedures are modelled on known procedures (especially those executable by hand) and adapted from them.

A major problem is why the old situation is perceived as similar to the new one. This point has been developped elsewhere (Richard, 1985). The basic idea is that this is done through a matching process based on the following conditions: the old situation has the same goal as the new one, there is a known procedure to reach the goal in the old situation and the procedure may be applied to the present situation. This means that the prerequisites allowing the subgoals to be realized are satisfied so that the procedure may be applied in the present situation. Thus the similarity on which analogical transfer is based is similarity to a prototype.

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Imprimé en France

par

l'Institut National de Recherche en Informatique et en Automatique